INSTRUCTION MANUAL

MODEL
TRM

TRANSISTOR-DRIVEN, MAGNETIC-AMPLIFIER REGULATED POWER SUPPLY

MODEL TRM-

NJE CORPORATION
20 Boright Avenue
Kenilworth, New Jersey

Telephone BRidge 2-6000
TWX Cranford 51

TABLE OF CONTENTS

Section	Title	Page
I	DESCRIPTION	1-1
	1-1. General	1-1
	1-2. Reference Data	1-1
	1-3. Description	1-1
	1-7. Ratings & Specification Charts	1-2
	1-8. Electrical Characteristics	1-6
II	INSTALLATION & OPERATION	2-1
	2-1. Unpacking	2-1
	2-2. Installation	2-1
	2-9. Operation	2-2
III	PRINCIPLES OF OPERATION	3-1
	3-1. General	3-1
	3-2. Block Diagram - Wide Range	3-1
	3-3. Block Diagram - Narrow Range	3-1
	3-4. Magnetic Amplifier Operation and Characteristics	3-1
IV	DETAILED CIRCUIT DESCRIPTION	4-1
	4-2. Primary Circuit	4-1
	4-3. DC Power Circuit	4-1
	4-6. Amplifier Power Supply	4-1
	4-10. Amplifier Description	4-3
	4-22. Overload Current Limiting Circuit & Short Circuit Protection	4-6
	4-23. Stability & Gain Controls	4-6
V	MAINTENANCE	5-1
	5-1. General	5-1
	5-2. Spare Modules	5-2
	5-3. Malfunctions	5-2
	5-4. No Output Voltage	5-2
	5-5. Low Output Voltage	5-3
	5-6. High Output Voltage	5-3
	5-7. Failure to Regulate, No Load	5-3
	5-8. Failure to Regulate, Full Load	5-4
	5-9. Excessive Ripple	5-4
	5-10. Instability	5-4
	5-11. Oscillation	5-5
	5-12. Regulation Check	5-5
	5-16. Feedback Amplifier Check	5-6
VI	APPLICATION NOTES	6-1

WARNING

THIS EQUIPMENT EMPLOYS VOLTAGES WHICH ARE DANGEROUS AND MAY BE FATAL IF CONTACTED BY OPERATING PERSONNEL. EXTREME CAUTION SHOULD BE EXERCISED WHEN WORKING WITH THIS EQUIPMENT.

CORRESPONDENCE AND ORDERING SPARE PARTS

1. Each NJE Power Supply has an identification label on the rear of the chassis which bears the model and serial number of the particular unit.

2. When requesting engineering data, reference should be made to the model and serial number and the component symbol number as shown on the applicable schematic.

3. When ordering spare parts, the information outlined in paragraph 2 should be given in addition to the NJE Part No. that appears on the parts list.

SECTION I

DESCRIPTION

1-1. GENERAL. The NJE TRM Transistor-Driven Magnetic-Amplifier Regulated Power Supply is designed for use in applications requiring a well regulated and stable source of DC power at high values of current.

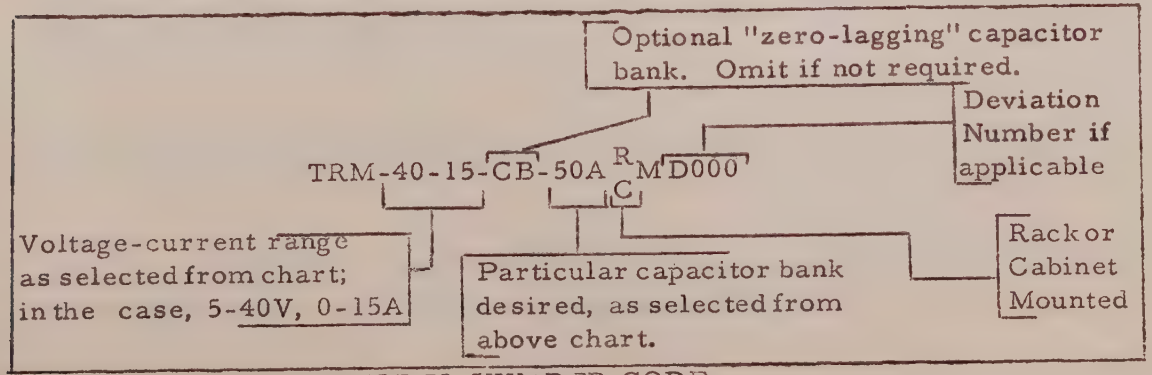
1-2. REFERENCE DATA. The electrical and physical characteristics of the Power Supply are presented in the following paragraphs.

1-3. DESCRIPTION. The model number contains descriptive information indicating the maximum output voltage, and the maximum output current. For example: The model number "TRM-40-15" indicates that the maximum output voltage is 40 volts, and that the maximum output current is 15 amperes.

1-4. A model number including the letters "CB" (followed by another number) indicates that a Capacitor Bank has been added in parallel with the output to reduce the normal voltage excursion resulting from an abrupt (step) change in line or load current. The capacitor bank exhibits an electrical flywheel effect, commonly referred to as "zero-lag" and described in detail below. For example: "TRM-40-15-CB-50A" indicates that this supply incorporates a capacitor bank rated 0.1 farad, 50 volts DC. See Table 2 for capacitor bank ratings and designations.

1-5. The standard model number is completed by the letters "-RM" or "-CM". The "-RM" designation indicates that the supply is a rack mounting unit incorporating an ammeter and a voltmeter with suitable scales. The "-CM" designation indicates that the equipment is supplied in a cabinet, and that meters are incorporated in the unit.

1-6. Supplies with minor deviations from the catalog specifications are so designated by the suffix "D____". The number following the "D" is a reference number only, with no descriptive significance.


Optional "zero-lagging" capacitor bank. Omit if not required.
Deviation Number if applicable
TRM-40-15-CB-50A R M D000
C
Voltage-current range as selected from chart; in the case, 5-40V, 0-15A
Particular capacitor bank desired, as selected from above chart.
Rack or Cabinet Mounted

MODEL NUMBER CODE

1-7. RATINGS AND SPECIFICATIONS CHARTS.

TABLE 1. BASIC POWER SUPPLY RATINGS

MODEL NUMBER	OUTPUT RANGE		Δ t* SECONDS	INPUT REQUIREMENTS	
	VOLTS	AMPERES		VOLTS	AMPS/PHASE
TRM-28-30	24-32	0-30	0.025	115V 60 cps 1 ph.	20A
TRM-28-60	24-32	0-60	0.025	208/220V 60 cps 1 ph.	17A
TRM-28-120	24-32	0-120	0.015	208V 60 cps 3 ph. 4-wire	20A
TRM-40-15	5-40	0-15	0.025	115V 60 cps 1 ph.	15A
TRM-40-30	5-40	0-30	0.025	115V 60 cps 1 ph.	30A
TRM-40-60	5-40	0-60	0.025	208/220V 60 cps 1 ph.	25A
TRM-40-120	5-40	0-120	0.015	208V 60 cps 3 ph. 4-wire	28A
TRM-80-7.5	10-80	0-7.5	0.025	115V 60 cps. 1 ph.	15A
TRM-80-15	10-80	0-15	0.025	115V 60 cps 1 ph.	30A
TRM-80-30	10-80	0-30	0.025	208/220V 60 cps 1 ph.	25A
TRM-80-60	10-80	0-60	0.015	208V 60 cps. 3 ph. 4-wire	28A
TRM-80-120	10-80	0-120	0.015	208V 60 cps 3 ph. 4-wire	55A

*"Turn-around time" used in zero lag equation below.

TABLE 1. BASIC POWER SUPPLY RATINGS - Continued

MODEL NUMBER	OUTPUT RANGE		Δt^*	INPUT REQUIREMENTS	
	VOLTS	AMPERES	SECONDS	VOLTS	AMPS/PHASE
TRM-160-7.5	20-160	0-7.5	0.025	115V 60 cps 1 ph.	30A
TRM-160-15	20-160	0-15	0.025	208/220V 60 cps 1 ph.	25A
TRM-160-30	20-160	0-30	0.015	208V 60 cps 3ph. 4-wire	28A
TRM-160-60	20-160	0-60	0.015	208V 60 cps 3 ph. 4-wire	55A

*"Turn-around time" used in zero lag equation below.

TABLE 2. SIZE AND WEIGHT TRM DC POWER SUPPLIES

RACK*			CABINET			Power Supply Models	Power Supply Approx. Wgt. (Lbs.)+	Capacitor Banks	Capacitor Banks Approx. Wgt. (Lbs.)+
Total Panel Height (Inches)	Max. Depth (Inches) **	Panel Width (Inches)	Height (Inches)	Depth (Inches)	Width (Inches)				
7	17-3/4	19	8-3/4	18	22			CB-15A CB-25A CB-50A CB-125A CB-200A	30
14	17-3/4	19	15-3/4	18	22	TRM40-15 TRM80-7.5	120	CB-15B CB-25B CB-50B CB-125B CB-200B	60
17-1/2	17-3/4	19	19-1/4	18	22	TRM28-30 TRM40-30 TRM80-15 TRM160-7.5	160		
19-1/4	17-3/4	19	21	18	22			CB-15C CB-25C CB-50C CB-125C CB-200C	90
24-1/2	17-3/4	19	28	18	22			CB-15D CB-25D CB-50D CB-125D CB-200D	120

TABLE 2. SIZE AND WEIGHT TRM DC POWER SUPPLIES - Continued

RACK*			CABINET			Power Supply	Power Supply		Capacitor Banks
Total Panel Height (Inches)	Max. Depth (Inches) **	Panel Width (Inches)	Height (Inches)	Depth (Inches)	Width (Inches)	Models	Approx. Wgt. (Lbs.)+	Capacitor Banks	Approx. Wgt. (Lbs.)+
26-1/4	17-3/4	19	28	18	22	TRM28-60 TRM40-60 TRM80-30 TRM160-15	250		
35	17-3/4	19	36-3/4	18	22	TRM28-120 TRM80-60 TRM160-30	450		
42	17-3/4	19	47-1/8	18	22	TRM40-120	450		
57-3/4	22	19	67-3/8	24	23-5/8	TRM80-120 TRM160-60	750		

1-8. ELECTRICAL CHARACTERISTICS.

METERS: An ammeter and voltmeter are furnished as standard equipment on all models: 4-1/2" rectangular accuracy ±2% of full-scale, single range.

POLARITY: All supplies can be floated up to 500V peak off ground. Either polarity may be grounded to chassis. A ground terminal is provided.

RIPPLE: All TRM units have less than 1% RMS ripple at any output voltage or current within rating.

STATIC LOAD REGULATION: The static load regulation of any TRM supply will not exceed 0.1% or 50 MV, whichever is greater, for 0-100% load change at constant line voltage.

TRANSIENT RESPONSE: The transient response of TRM supplies is best described by two parameters: The so-called "turn-around" time, and the "response time constant". These are depicted in Figure 1 below. The 'turn-around" time, Δt given in Table 1, is used for computing the necessary "zero-lag" capacitor bank requirement for an allowable output voltage deviation, ΔV, which results from either a load current step, ΔI, or from a line voltage step ΔE_1. In the formula given below I_o is the maximum current rating of the supply. E_1 is the nominal line voltage rating of the supply, and C is the capacitor bank capacitance in farads. The table lists conservative values of Δt for both single-phase and three-phase units. The formula given is approximate, but conservative.

$$C = \frac{\left[\Delta I + \frac{\Delta E_1}{E_1} I_o\right] \Delta t}{\Delta V}$$

example: To determine the capacitance required to hold the maximum output voltage excursion

TRANSIENT RESPONSE: (Cont.)

of a TRM-40-15 to 1 volt, against the worst simultaneous combination of a 3-ampere load "step" and a 10% line step:

ΔV = 1.0 volt

ΔI = 3.0 amperes

ΔE_1 = 10% of E_1, so that $\frac{\Delta E_1}{E_1} = 0.1$

Δt (from chart above) = 0.025 seconds

I_o = 15 amperes

$$C = \frac{[3.0 + (0.1)\ 15]\ 0.025}{1.0} = 0.112 \text{ farads}$$

Use 50-volt, 0.2 farad bank (CB-50B) selected from Table 4.

TABLE 3. ZERO LAG CAPACITOR BANKS

	15 volts (for 10V supplies)	25 volts (for 20V supplies)	50 volts (for 40V supplies)	125 volts (for 80V supplies)	200 volts (for 100V supplies)
size A	15A 0.4 Farad	25A 0.2 Farad	50A 0.1 Farad	125A 0.05 Farad	200A 0.03 Farad
size B	15B 0.8 Farad	25B 0.4 Farad	50B 0.2 Farad	125B 0.1 Farad	200B 0.06 Farad
size C	15C 1.2 Farad	25C 0.6 Farad	50C 0.3 Farad	125C 0.15 Farad	200C 0.09 Farad
size D	15D 1.6 Farad	25D 0.8 Farad	50D 0.4 Farad	125D 0.2 Farad	200D 0.125 Farad

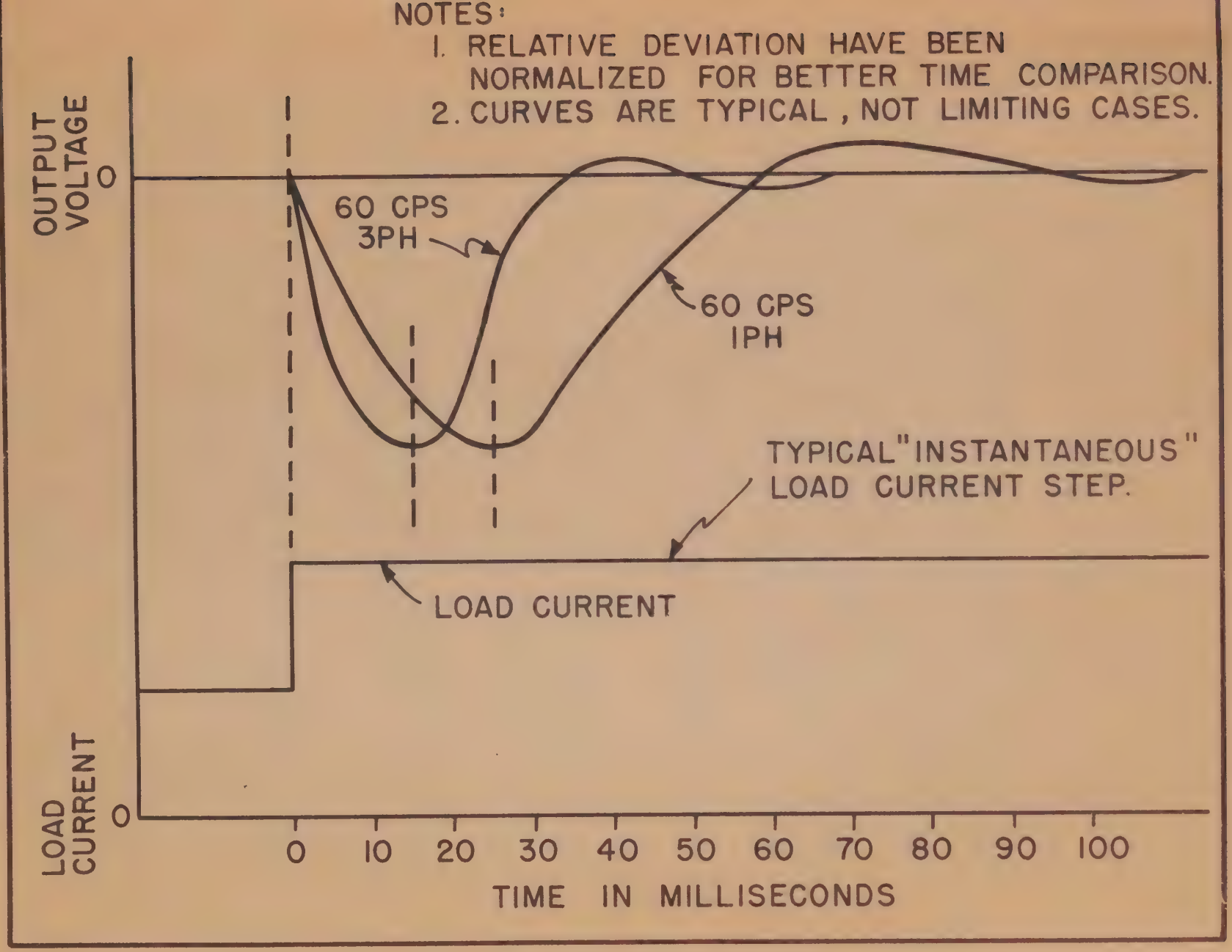


Figure 1. Typical Transient Response

SECTION II

INSTALLATION AND OPERATION

2-1. UNPACKING. The complete shipment consists of one or more large cartons or crates containing the Power Supply. All cartons should be opened immediately upon receipt and the contents inspected for shipping damage. The Power Supply was checked electrically and mechanically before it left the factory, and is warrented to be in perfect operating condition. This guarantee does not cover possible damage incurred during shipment. Therefore, any evidence of mishandling, such as broken, deformed, or missing parts, should be brought to the attention of the transportation company and a claim should be enetered. Open the cabinet doors and inspect all components and wiring, both on the chassis and panel, as well as the mechanical condition of the housing.

2-2. INSTALLATION. The cabinet model equipment requires no installation outside of the connection of a good ground to the appropriate terminal at the rear of the equipment.

2-3. The rack model is notched for installation in a standard 19-inch relay rack. It should be securely fastened in place and a good ground connected to the appropriate terminals at the rear of the cabinet. Heavier units require bracing beneath the chassis. This is best accomplished by mounting angle iron onto the walls of the rack at an appropriate level to provide a suitable support for the equipment.

2-4. COOLING IS REQUIRED ON ALL STANDARD MODELS OPERATING ON 208/220V, SINGLE PHASE OR 208V, THREE PHASE. An exhaust fan should be installed in the cabinet above the power supply. The power supply is rated for maximum 45° C ambient conditions.

2-5. To permit monitoring and regulating the DC output voltage without introducing an error due to voltage drop in the cable connecting the supply and the load, the input of the correction amplifier has been brought out to the Positive Sensing and Negative Sensing terminals at the rear of the equipment. These must be connected through separate sensing leads directly to the load, observing correct polarity. A pair of 20-gauge, stranded, and shielded wires are recommended. While it is possible to jump the sensing leads directly to the positive and negative output terminals of the supply, so doing will cause the load leads to be included as part of the external load, and the actual voltage at the remote load will vary accordingly with changes in load current. See the schematic diagram at the back of this manual for correct terminal numbers.

2-6. The input and output connections are made at the rear of the chassis. Although all terminals are marked for proper connections, consult the schematic diagram at the back of this manual to confirm the terminations used for input line, input ground, output load, ground, and sensing connections.

2-7. The output of the supply can be connected for either polarity, and can be floated as much as 500 volts (peak) above or below chassis ground. However, the most stable operation will be obtained when one of the two output terminals (POS or NEG) is connected to the chassis ground (GRD) either by a jumper or through a 0.1 microfarad, 600-volt capacitor.

2-8. In those models in which two cabinets or two rack-mounted chassis are employed, the interconnecting cable will be found in the main unit. Connect this cable to the appropriate terminals on the second unit. The schematic can be used to confirm the proper terminal points.

2-9. OPERATION.

a. Energize the power supply by operating AC switch S1. The pilotlight should indicate the ON condition.

b. Set the COARSE ADJUST to obtain the approximate required voltage.

c. Set the FINE ADJUST as desired. Note: In some models, there is a slight tendency for the equipment to oscillate or "hunt" at low range voltage adjustments. This can be cleared by adjusting the COARSE and FINE controls in a combined adjustment with the FINE ADJUST near its maximum setting.

d. Some high power models have a voltage range selector switch which must be set as desired.

SECTION III

PRINCIPLES OF OPERATION

3-1. GENERAL. The NJE Corporation TRM-Line Power Supplies are designed in two basic circuitry configurations for use in "wide-range" and "narrow-range" models. The "wide-range" units operate over approximately an 8:1 voltage span. The standard catalog line of equipment includes models operating over three ranges, 5-40 volts, 10-80 volts, and 20-160 volts, respectively. The "narrow-range" units operate from 24 to 32 volts.

3-2. BLOCK DIAGRAM - "Wide-Range" Models. A simplified block diagram illustrating the basic elements of the circuit and the signal flow, is shown in Figure 2. The AC voltage from the magnetic amplifier is converted to an appropriate value by the power transformer and rectified by a full-wave, single or three-phase silicon rectifier system. A filter smooths the pulsating DC output of the rectifier, providing a low-ripple DC voltage to the output. The output voltage furnished to the load is sampled by a DC feedback amplifier which compares this voltage with a stabilized reference voltage and amplifies the difference between the two voltages. The output of the amplifier is used to control the magnetic amplifier in such a way that it counteracts any change in the DC output voltage by varying the AC input to the power transformer, thereby furnishing an essentially constant voltage to the external load, despite variations in input line voltage or output load current. Note that an auxiliary power supply is used to provide the necessary voltages for the amplifier and reference network.

3-3. BLOCK DIAGRAM - "Narrow-Range" Models. A simplified block diagram for "narrow-range" models is shown in Figure 3. The circuit configuration is quite similar to the "wide-range" units except for two basic differences. The power transformer and magnetic amplifier elements are interchanged, providing what is frequently referred to as 'secondary' control. The magnetic amplifier controls the input to the rectifier circuit, whereas in the "wide-range" (primary) control units, the magnetic amplifier controls the input to the power transformer. The second difference in the two circuits is that the "narrow-range" supplies do not utilize an auxiliary supply to power the amplifier and reference. Power for the latter circuits is derived directly from the main supply output.

3-4. MAGNETIC AMPLIFIER OPERATION AND CHARACTERISTICS. Figure 4A illustrates a basic AC choke, or inductive reactor. Placed in series with an AC source and load, it presents a fixed impedance equal to 2π times the frequency times the inductance of the reactor. If a concentric "control" winding were placed on the center leg of this core and DC current caused to flow through it, the resultant DC flux would tend to saturate the core and thus alter the inductance. The control obtained would be proportional to

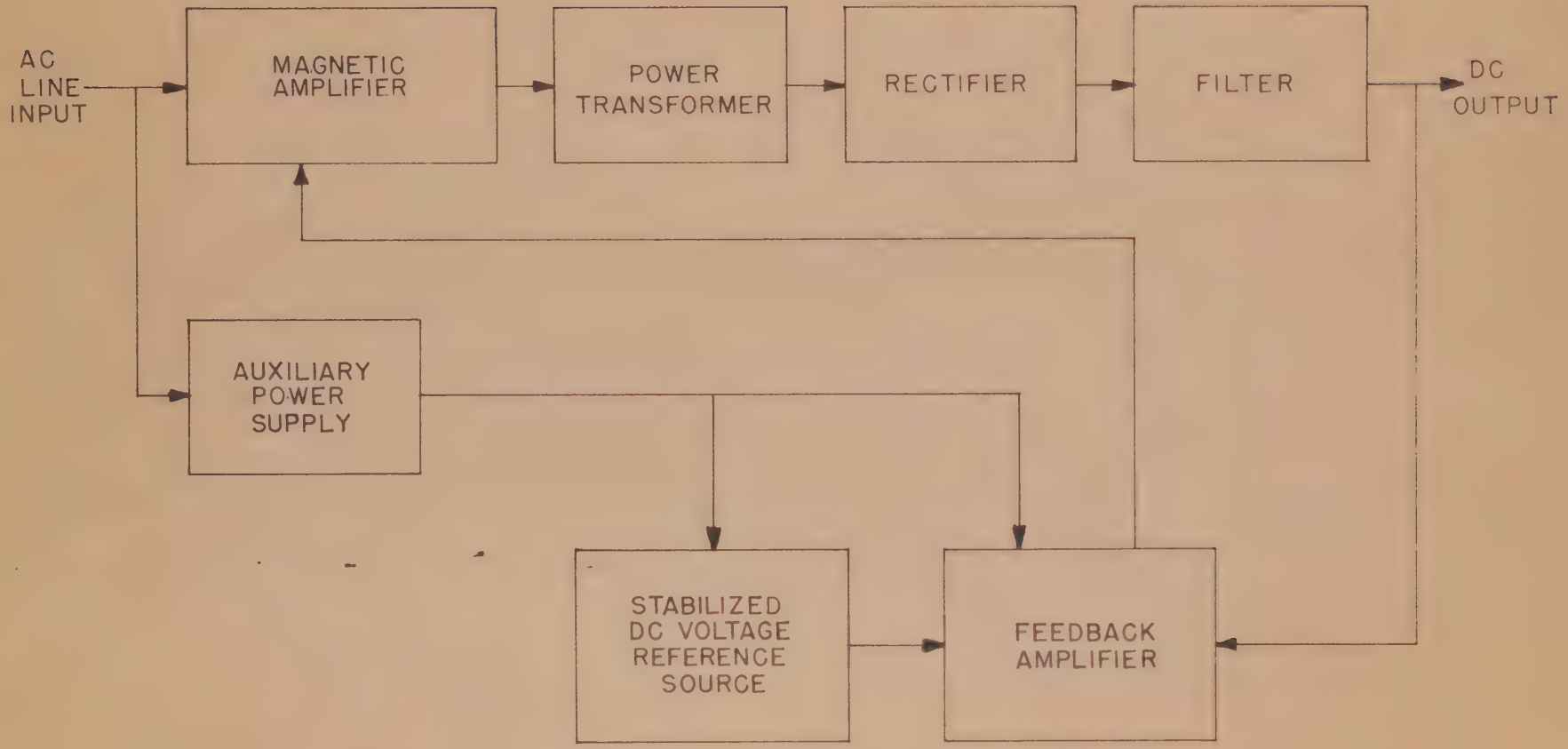


FIGURE. 2 REGULATED DC POWER SUPPLY, SIMPLIFIED BLOCK DIAGRAM. WIDE RANGE MODELS

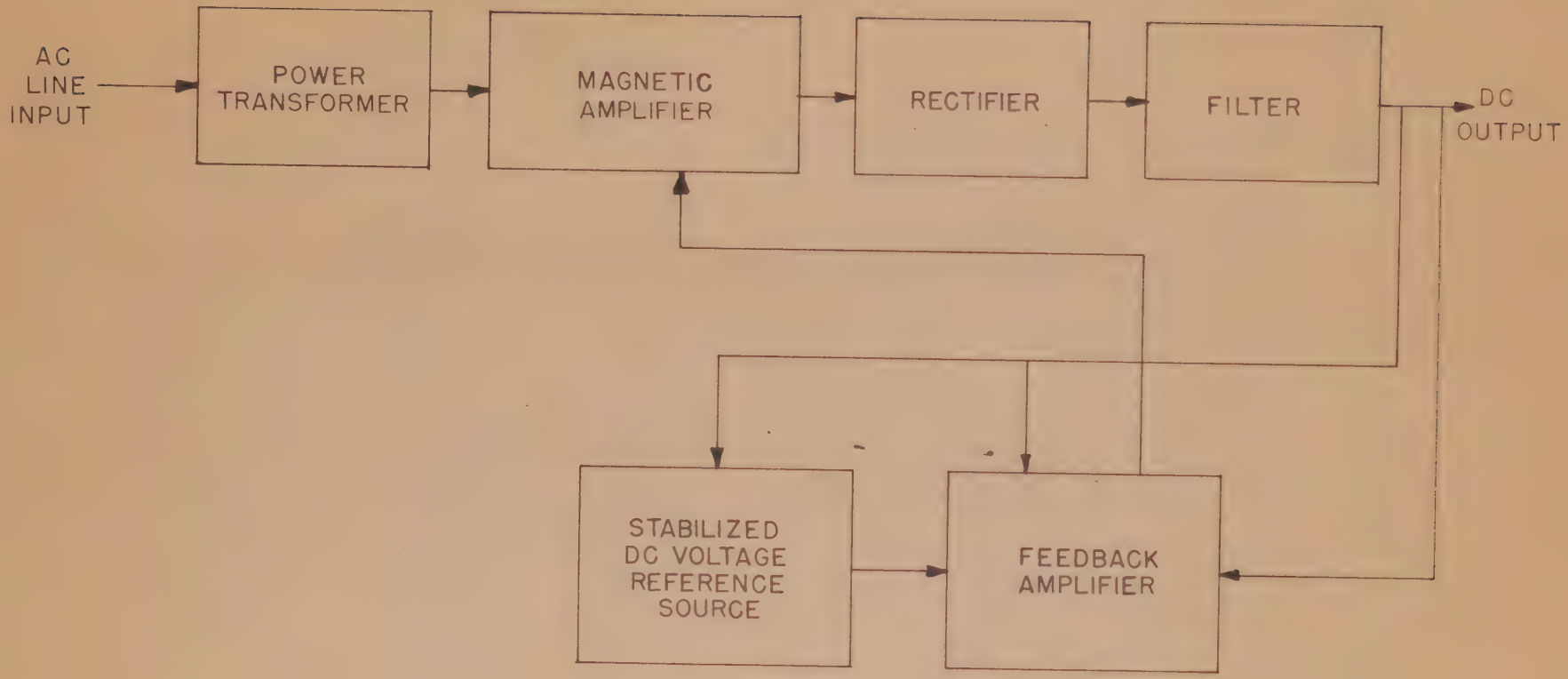


FIGURE. 3 REGULATED DC POWER SUPPLY, SIMPLIFIED BLOCK DIAGRAM. NARROW RANGE MODELS

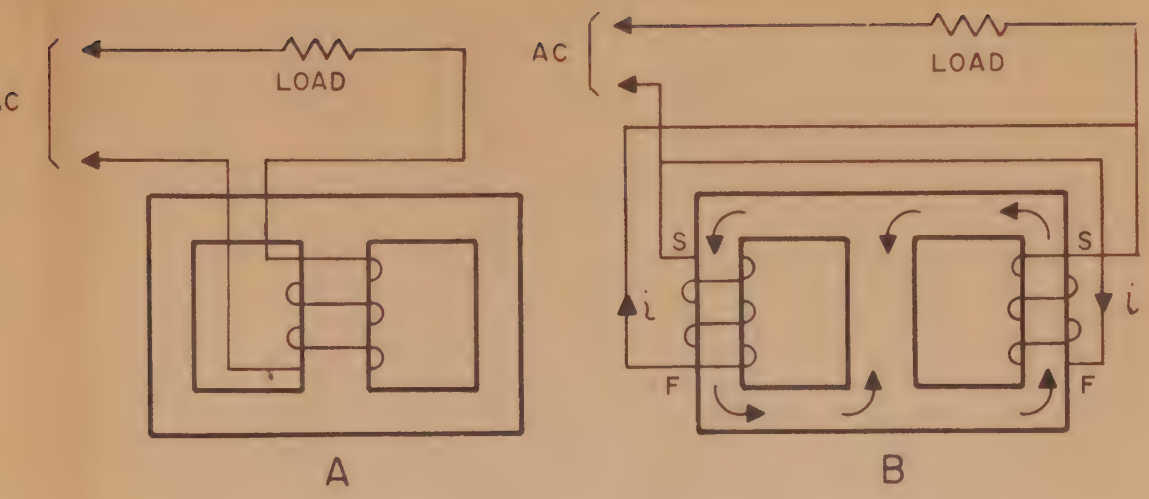
the product of the number of turns in the control winding and the current flowing through it. Consequently, a very small current (flowing through a large number of turns) could control a large load current. This configuration is impractical since the AC winding would induce a destructive AC voltage in the DC (control) winding.

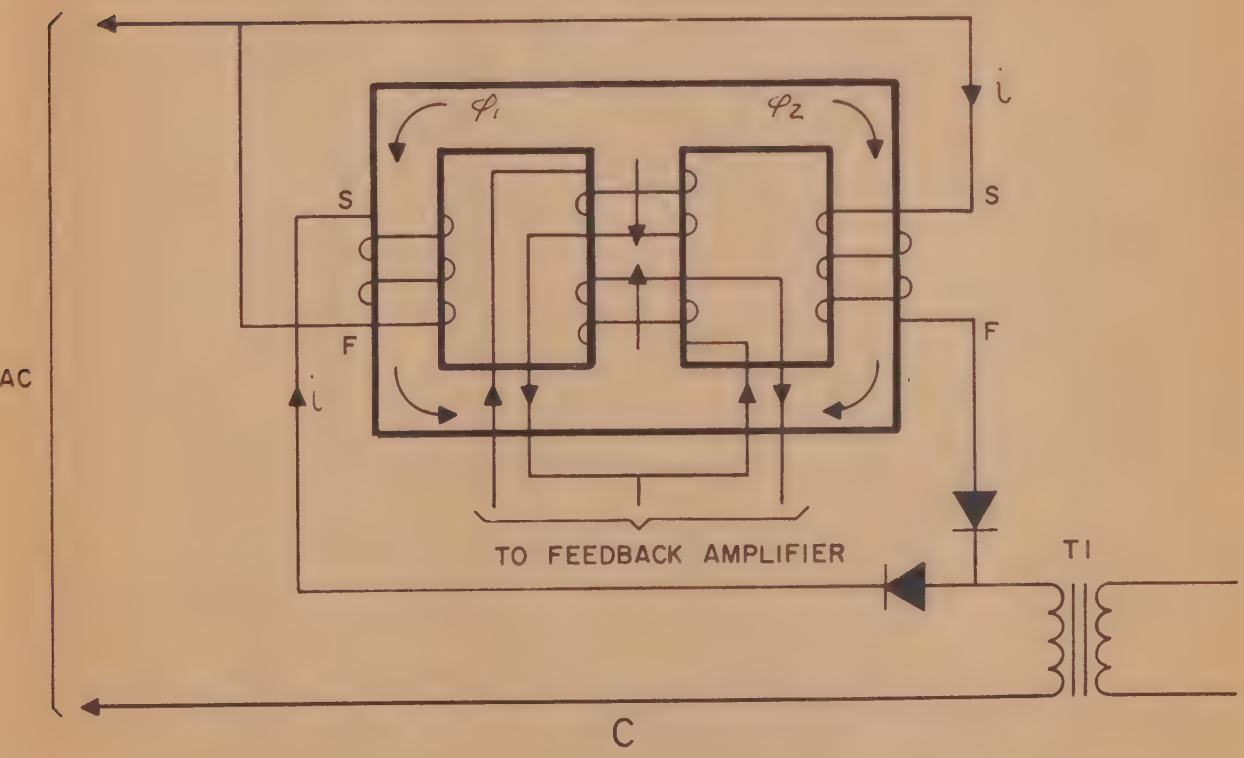
3-5. Figure 4B illustrates a modification of the basic reactor. The AC winding has been split and placed on the outside legs. These windings are tied in parallel, with polarity such that the instantaneous fluxes are additive around the periphery of the core, but cancel out in the center leg. If a DC control winding were to be placed on the center leg of this core the desired result would be achieved. This configuration is commonly referred to as a Saturable Reactor. Note that the polarity of the DC current is unimportant.

3-6. Figure 4C represents a further modification of 4A. Here, in addition to placing the AC windings on the outside legs, two control windings have been added to the center leg, and rectifier diodes have been added in series with the AC windings. The diodes in series with the AC windings polarize the load current flowing through the windings, and cause the device to become self-saturating, thus providing "internal" positive feedback. Further, the diodes cause each AC winding to conduct current only on alternate half-cycles. The degree of conduction during any half-cycle is predetermined during the preceding cycle, partly by the DC saturation resulting from the unidirectional flow of load current in the preceding half-cycle, and partly by the DC saturation caused by the control windings.

3-7. As indicated in Figure 4D, a typical transfer curve, where the ordinate represents units of load current and the abscissa represents units of control current, when the control current flow is zero, conduction will be approximately 50 percent. A negative control current will reduce the output; a positive control current will increase the output.

3-8. See Figure 5 below for Typical Voltage Waveforms at the magnetic amplifier output for the various modes of operation indicated. B and C represent normal extremes in operating conditions. Deviation from these waveforms, for the conditions indicated, and especially a lack of symmetry is a definite symptom of malfunction.


LOAD
AC
LOAD
S
S
i
i
F
F
A
B


AC
i
S
S
F
F
i
TO FEEDBACK AMPLIFIER
T1
C

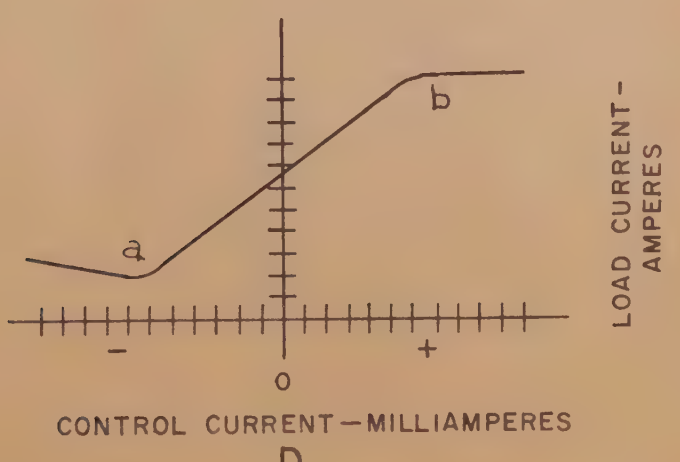
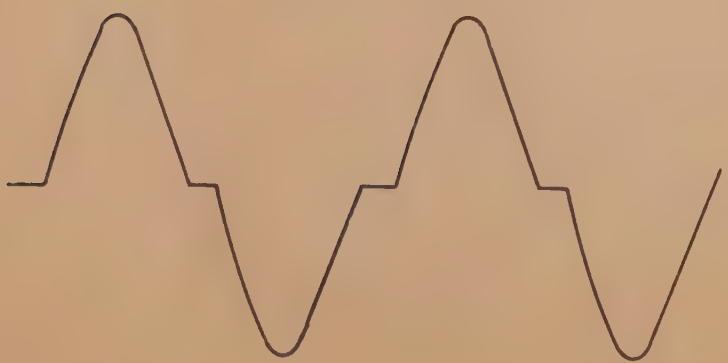

b
a
LOAD CURRENT-AMPERES
-
0
+
CONTROL CURRENT—MILLIAMPERES
D

Figure 4

A. Nominal Line, Nominal Load, Nominal Voltage

. High Line, No Load, Minimum Output Voltage



C. Low Line, Full Load, Maximum Output Voltage

Figure 5. Typical Voltage Waveforms At Magnetic Amplifier Output

SECTION IV

DETAILED CIRCUIT DESCRIPTION

4-1. Figure 6 is a detailed schematic diagram of a typical TRM supply. The unit selected for the following discussion is a single-phase, primary "mag-amp" controlled, "wide-range" type supply. Although the description which follows is directly applicable to Figure 6, the details are quite similar for the entire catalog line of supplies. Circuit variations in different models involve such items as three-phase rectification, secondary "mag-amp" control ("narrow-range" units), and differences in feedback and stabilization networks. The amplifier is standard for all models and the description given herein is applicable to all units. The exact schematic for the particular model purchased has been supplied at the end of this manual.

4-2. PRIMARY CIRCUITRY. The power supply is energized by connecting the AC line voltage to the input terminals TB1-1, TB1-2, and closing switch S1. The main line is protected by AC fuse F1, and the control line is protected by CONTROL fuse F2. The closing of S1 energizes relay K201 in the amplifier circuit. This closes contact K201A applying line voltage to AC indicator DS1, as well as contactor K1, thereby applying line power to the magnetic amplifier and rectifier circuitry.

4-3. DC POWER CIRCUIT. Line voltage is fed through contact K1A to the "gates" (AC windings) of magnetic amplifier SL1. Rectifiers CR1 and CR2 provide the necessary uni-directional current flow through the "magamp" gates. (See description in Section 3, paragraph 3-6.) The controlled output of the magnetic-amplifier is applied to power transformer T1 which converts the primary voltage to an appropriate value on its secondary winding to obtain the necessary output voltage. The transformer voltage is rectified by silicon diodes CR3, 4, 5, and 6 providing a pulsating DC output which is smoothed by the 2-stage choke input filter L1, C1, L2, C2.

4-4. Variable resistor R1 and fixed resistor R2 are the power supply bleeders, and are protected by bleeder fuse F3. The variable resistor R1 is ganged with the main output voltage control to provide a relatively constant bleeder current over the entire range of operation. This element is required because of the extremely wide operating range of these supplies. Voltmeter M2 monitors the output voltage and ammeter M1 in conjunction with shunt R3 meters the output current. The output terminals are TB2-4 and TB2-2.

4-5. Plug and receptacle J1 and P1 serve as a wiring disconnect for the equipment front panel.

4-6. AMPLIFIER POWER SUPPLY. When line switch S1 is closed power is applied to amplifier power transformer T201 through the amplifier

INPUT
115 VAC
60 CPS
1PH

TB1-1 — AC FI — KIA — SL1 GATE 1 (1, 2) — CR1 — 2 — T1 — 3 — CR5 / CR6 / CR4 / C

SL1 GATE 2 (4, 3) — CR2

J1-1 / P1-1 — CONTROL F2

SL1 CONT. 1 (6, 5) — CONT. 2 (7, 8)

T1 1 — 4

TB1-2

AC S1

J1-3 / P1-3 — AC DS1 — KI

TB1-3 — GRD

P1-2 / J1-2 — P1-4 / J1-4

A1

TB201-6 — TB201-5 — TB201-4 — TB201-2 — TB201-1 — TB201-3

K201A

T201 (2, 4, 1, 3)

J201-M — M — CR103 — CR104

K201B

J201-F — F — CR102 — CR101

R103 2000 3W — R105 2000 3W

R202 500 10W — TB202-5

J201-R — R

R104 200 1/2 W (3, 2, 1)

J201-K — K — TB202-1

Q101 — Q102

R201 100 25W

Q201 — Q202

+9V — +9V — +9V

TB202-6 — J201-L — L

TB202-4 — J201-C — C — R101 200 1/2 W (3, 2, 1)

C102 .01UF 400V

TB202-3 — J201-D — D

TB202-2 — J201-J — J

Q103

L201 (1, 3, 4, 2)

R102 2500 3W

J201-A — A

C201 2250UF 80V — K201

50V

R106 1000 3W — R107 1000 3W

J201-B — B

A1A1

DC
F4
L1
L2
C1
C2
F3
J1-13
P1-13
1
2
3
R1
GANGED
TO R4
P1-15
J1-15
R2
C3
25
R4
COARSE
ADJUST
J1-9
P1-9
TB2-4
POS OUT
POS SENS
TB2-5
3
2
1
GANGED
TO R1
1
2
3
R5
FINE
ADJUST
V
M2
P1-8
J1-8
M1
A
P1-7
J1-7
C4
P1-5
J1-5
P1-6
J1-6
TB2-3
GRD
R6
TB2-2
NEG OUT
R3
NEG SENS
TB2-1
TB201-7
TB 201-8
TB201-10
TB 201-9
+18V
CR105
R110
10K
3W
R112
10K
3W
Q106
R115
330K
1/2W
S
J201-
S
C103
25UF
50V
R116
220K
1/2W
R114
10K
3W
R113
1000
3W
CR106
CR108
P
J201-P
Q104
Q105
CR107
CR110
CR111
0V
N
J201-N
CR109
E
J201-E
1
2
3
R108
200
1/2W
C101
70UF
15V
R117
560
3W
R109
3900
3W
R111
10K
3W
R119
560
3W
-18V
-6.4V
1
2
3
R118
200
1/2W
H
J201-H
RECEIVED
MAR 31 1980

disconnect points TB201-1 and TB201-2. The dotted line within the amplifier subassembly block represents the printed-circuit assembly. The numbers adjacent to the terminals on the dotted lines represent printed circuit disconnect terminals.

4-7. T201 secondary voltage is rectified by bridge rectifier CR101, 102, 103, 104 and filtered by capacitor input filter C201. DC relay K201 is energized through dropping resistor R102 when the amplifier power source is operating properly, and, as described in paragraph 4-2 above, this relay interlocks the main line contactor K1.

4-8. Positive DC voltage is fed through printed-circuit terminal J to the Q201-Q202 heat sink (to be described below), then dropped across R202, and finally returned to the printed circuit through terminal R. Zener diodes CR108 and CR107 are thereby energized to provide stable bias voltages of ±18 voltage with respect to the amplifier common return terminals TB201-6. Note that this terminal is returned to the Negative Sensing output terminal TB2-1 to be described below.

4-9. The -18-volt level of CR107 provides a stable bias voltage for the main system reference. This consists of zener diode CR109 in conjunction with resistor R117 and provides a highly stable potential of -6.4 volts for use as a comparison voltage for the feedback amplifier. These zener diodes function in a manner analogous to that of a gaseous voltage regulator tube, providing a relatively constant output voltage across their terminals despite variations in the conducted currents.

4-10. AMPLIFIER DESCRIPTION. The feedback amplifier consists of three balanced stages of amplification, assuring minimum sensitivity to fluctuations in ambient temperature or operating voltages. The input signal for the amplifier is derived from a sensing voltage divider connected across the output of the supply. This divider consists of resistors R117 and R118 in the amplifier, and variable resistors R4 and R5, and fixed resistor R6 on the main chassis. The resistance value of R4 and R5 in series determins the operating value of the DC output voltage of the supply in a manner which will be explained below. Resistor R1 is ganged to resistor R4 in order to provide an approximately constant current preload. Resistor R5 controls the output voltage in the same manner as does R4 but, being of much smaller value, effects only a small voltage variation as it is rotated from minimum to maximum. This control acts as a vernier, for precise adjustment of the DC output voltage.

4-11. The negative end of the sensing voltage divider (negative end of resistor R118) is returned to the negative output of the supply through zener diode CR109, the neutral bus terminal TB201-7 of the amplifier, and the negative sensing lead TB2-1. The diode CR109, in conjunction with its load resistor R119, provides a highly stable potential of 6.4 volts DC for use as a comparison voltage by the input stage Q104-Q105 of the feedback amplifier.

When the output of the power supply (measured at the load) is precisely at its selected nominal value, the voltage at the base of transistor Q105 (derived from the sensing voltage divider at terminal TB201-8) is at the same level as the base of transistor Q104, and the input stage is in balance. Under this condition, any tendency of the load voltage to vary in either direction will unbalance the amplifier, resulting in corrective action which compensates for the impending change, and holds the load voltage at its established value, as explained below. Note that the amplifier signals are derived from the POSITIVE and NEGATIVE SENSING terminals TB2-5 and TB2-1. These terminals are connected as desired to the remote load point to assure proper regulation at the external load point.

4-12. Transistors Q104 and Q105 are NPN type units, operated in common-emitter mode, and connected as a balanced differential amplifier. Their outputs, taken across load resistors R110 and R112, are direct-coupled to the bases of the succeeding emitter-follower amplifier stages, Q101 and Q102. The outputs are emitter-follower coupled to the bases of the succeeding differential amplifier stage, Q201-Q202. The output of this stage is fed directly to the control windings of the saturable reactor SL1 of the magnetic amplifier regulator through choke L201.

4-13. Regulation of the DC output is performed by the magnetic amplifier assembly, consisting of saturable reactor SL1 and rectifiers CR1 and CR2. See paragraph 3-4 for a brief theoretical discussion on the operation of magnetic amplifiers.

4-14. As directed by the feedback amplifier, the magnetic amplifier adjusts its conductivity in series with the input to power transformer T1 to continuously absorb an AC voltage proportional to the difference between the unregulated DC supply voltage and the selected DC output voltage, regardless of input line conditions or load current drawn.

4-15. The DC output voltage of the supply is precisely proportional to the AC voltage impressed on the primary winding of the power transformer T1. The secondary winding of T1 is designed to provide at least enough AC voltage to rectifiers CR3 through CR6 and filter L1, C1, L2, C2 to produce the maximum rated DC voltage under the most severe line and load conditions, i.e., low line and full load.

4-16. The sequence of corrective action around the feedback loop is as follows: The input to transistor Q104 is the zero reference level -- in this case the voltage at the negative terminal of the load. The input to transistor Q105 is the difference between the voltage across diode CR109 (the reference voltage) and the voltage on the sensing voltage divider resistors R117 and R118 at TB201-8. When the DC load voltage is at the selected value, the voltage across these resistors and the voltage across diode CR109 are equal, though of opposite polarity, and cancel each other out, so that the base of Q105 is at the same potential as the base of Q104 and the outputs

of the two transistors are balanced. When the load voltage tends to deviate from the selected value in either direction, due to a change in load current or in input line voltage, this causes the voltage on the sensing divider resistor R117 and R118 to differ from the voltage across the reference diode CR109, and the difference (or "error") voltage unbalances the amplifier stage Q104-Q105. This difference appears in amplified form in the output of this stage, and is further amplified by the subsequent amplifier stages before being applied to the control windings of SL1 causing SL1 to increase or decrease its conductivity in accordance with the error signal so that its overall voltage drop absorbs the impending variation in load voltage, maintaining an essentially constant value of voltage across the load terminals. Capacitor C3 assists the amplifier in responding to rapid changes in load voltage by bypassing a portion of the sensing circuit. The more rapid the change, the greater is the initial transfer of voltage direct to the input of the amplifier, enabling it to anticipate any radical load variation before the excursion becomes significant.

4-17. The sensitivity and speed of response of the corrective feedback circuit is such that the above-described action occurs almost instantaneously, and the actual excursion of the load voltage is held to a very small value. The circuit is a true proportional regulator, and must allow a small but finite "error" to exist between the required and actual regulated voltage, so that this error, however small, can generate the correction signal. By proper circuit design, the error is held to a value which remains within the specified regulation allowance of the power supply.

4-18. When resistors R4 and/or R5 are readjusted to produce a different value of output voltage, the circuit makes a correction similar to that described above. Altering the resistance in the sensing voltage divider unbalances the input stage of the feedback amplifier, which then causes the circuit to produce a new value of voltage such that the drop across resistors R117-R118 again equals the drop across diode CR109. Reducing the value of resistor R5 for example, momentarily increases the drop across R117-R118 (assuming a constant value of output voltage). However, this unbalanced condition at the amplifier input causes the DC output voltage to decrease until the drop across R117-R118 again equals the drop across CR109 and the circuit stabilizes at this new operating point, establishing a lower value of DC output voltage.

4-19. Resistor R118 in the amplifier is provided to permit compensating for manufacturing tolerances in diode CR109, its load resistor R119, and resistor R117. (This resistor is adjusted at the factory and locked.) If any of these components is replaced, check to see that full rated output voltage of the supply is obtainable at full load, with coarse and fine voltage controls at maximum clockwise position, with line voltage of 105 volts. If not, readjust R118 to provide full voltage under these conditions.

4-20. Amplifier levels are indicated on the schematic diagram for trouble-shooting purposes.

4-21. TURN ON OVERSHOOT SUPPRESSION. The network consisting of transistor Q106, diode CR106, capacitor C103, resistors R113, R114, R115, R116 and relay contact K201B is designed to minimize the output voltage overshoot when the power supply is initially energized as well as to reduce peak in-rush currents to a minimum. For a short interval equal to the pull-in period of K201 after the AC ON switch S1 is energized, contact K201B remains closed, effectively short-circuiting R115. This causes capacitor C103 to be fully charged with respect to the plus and minus 18-volt amplifier levels, and places the base of Q106 at +18 volts. This voltage causes the main amplifier input base, Q105 to experience a signal in a direction which tends to maintain the output voltage at a low level. When contact K201B opens, in approximately 50 milliseconds after S1 is operated, capacitor C103 begins to discharge, gradually reducing the voltage at the base of Q106 until it drops below the steady state level of Q105 base. This allows the output voltage to rise at a reasonably slow rate, preventing any significant overshoot. Diode CR106 decouples the turn-on circuit from the main amplifier after the capacitor has discharged below the Q105 base level.

4-22. OVERLOAD CURRENT LIMITING CIRCUIT AND SHORT CIRCUIT PROTECTION. Transistor Q103, and resistors R108 and R109 comprise the current limiting network of the supply. A signal is supplied to printed-board terminals E and H which is derived from the voltage drop across the ammeter shunt, and is consequently proportional to the load current. When this voltage, and consequently the load current, exceeds a preset value determined by R108, Q103 begins to conduct causing a signal to appear on the base of Q102. This signal is such that it causes the output voltage to decrease. The effects of the main input signal to the amplifier at Q105 are overcome by the clamping action of CR105. The result is that the load current cannot be increased beyond the setting (approximately 125% rating)-- the output voltage decreases as required to maintain the fixed overload limiting value. As a matter of fact, if required to do so, the output voltage will reduce to zero, effectively allowing the power supply to operate into a dead short circuit on the output terminals. The overload condition will be maintained by the power supply for a period of 1 to 2 minutes until F4 (DC) fuse de-energizes the system providing a second line of protection beyond the 'electronic' overload protection system.

4-23. STABILITY AND GAIN CONTROLS. Capacitors C101 and C102 are required for high frequency stabilization in the amplifier. Variable resistors R101 and R104 are gain controls, and are adjusted to suppress low frequency oscillation. The lower the setting of these resistors, the lower is the gain of the amplifier, and the greater the stability.

SECTION V

MAINTENANCE

5-1. GENERAL. This section is arranged in the form of a trouble-shooting chart, with symptoms listed approximately in accord with the frequency of occurrance. Possible causes for each, and their remedies, are listed in logical succession beginning with the most common, to facilitate rapid location and isolation of a defective element.

5-2. SPARE MODULES. Where practical, it is recommended that one or more spare feedback amplifiers and rectifier assemblies be kept available for use in maintenance. This will reduce down time to a minimum, and permit easy testing by direct substitution, making it possible to repair a defective module at some convenient time and avoid prolonged interruption of operation.

5-3. MALFUNCTIONS. The various ways in which DC power supplies can deviate from normal operation are listed below. Each condition is treated separately in the charts that follow. Symbol designations refer to the schematic diagram in Section III.

MALFUNCTION	TYPICAL MAGNITUDE
1. No output voltage at any control setting.	Zero or negative DC output voltage.
2. Low output voltage.	Maximum output voltage obtainable is less than rating.
3. High output voltage.	Minimum output voltage not obtainable at no load.
4. Failure to regulate, No Load.	Output voltage out of regulation region in line voltage.
5. Failure to regulate, Full Load.	Output voltage out of regulation region.
6. Excessive ripple.	RMS ripple exceeds specification.
7. Instability.	
A. Random large excursions.	Output voltage "hops" intermittently by 5% or more, with constant load.
B. Gradual drift in one direction.	Output voltage changes by 1% or more per minute, after 15-minute warmup.

MALFUNCTION	TYPICAL MAGNITUDE
C. Excessive drift under heavy load only.	Output voltage changes by 1% or more per minute after a 15-minute warmup, but only after application of a heavy load.
8. Oscillation.	
A. Low frequency (motorboating).	At constant load, output voltage exhibits relaxation modulation at or below 30 cycles per second.

5-4. NO OUTPUT VOLTAGE.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Pilot light DS1 not lit.	1. No line power, or defective input connection.	1. Check power source, lines and connections.
	2. Input fuse F1 blown.	2. Replace fuse. If fuse blows repeatedly, do not overfuse. Check subsequent circuits for short or overload.
	3. Control fuse F2 blown.	3. Replace fuse.
	4. Dead short on output circuit.	4.
	a. External	a. Check load circuit.
	b. Internal	b. Shorted filter capacitor C1 or C2, or wiring short.
	5. Auxiliary power supply defective.	5.
	a. Capacitor C201.	a. Replace.
	b. Diodes CR101-104.	b. Replace.
	6. Rectifier, CR3-6 shorted.	6. Replace.
B. Pilot light DS1 lit.	1. Choke L1 or L2 open.	1. Replace.
	2. Meter shunt R3 open.	2. Replace.
	3. DC fuse, F4 blown	3. Replace.

SYMPTOM	POSSIBLE CAUSE	REMEDY
	4. Transformer T1 open.	4. Replace.
	5. Reactor SL1 open.	5. Replace.
	6. Defective relay, K1 or K201.	6. Replace.

5-5. LOW OUTPUT VOLTAGE.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Regulated AC at T1 Primary normal as indicated by voltage waveform.	1. Check amplifier transistors.	1. See paragraph 5-16.
	2. Check reference zener diode CR109.	2. Replace.
	3. Shorted feedback capacitors C3 or C4.	3. Replace.
	4. Open resistor in amplifier.	4. Replace.

5-6. HIGH OUTPUT VOLTAGE.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Output voltage can not be controlled down.	1. Shorted Mag. Amp. rectifier CR1 or CR2.	1. Replace.
	2. Fuse F3 (in bleeder circuit).	2. Check bleeder resistor. Replace fuse.
	3. Shorted capacitor C101 or C102.	3. Replace.
	4. Transistors in amplifier.	4. See paragraph 5-16.
	5. Divider network open. Check resistors.	5. Replace as required.

5-7. FAILURE TO REGULATE, NO LOAD

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Output voltage variations proportional to	1. Fuse F3 in bleeder resistor circuit.	1. Check resistors. Replace fuse.

SYMPTOM	POSSIBLE CAUSE	REMEDY
input voltage variations.		
	2. Leaky transistor in amplifier.	2. See paragraph 5-16.
	3. Open R202	3. Replace.

5-8. FAILURE TO REGULATE, FULL LOAD.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Severe output voltage regulation with load change.	1. One of the Mag. Amp. rectifiers, CR1 or CR2, is open.	1. Replace.
	2. Open DC rectifier CR3, 4 (5 or 6 if used).	2. Replace.
	3. Defective transistor(s) in feedback amplifier.	3. See paragraph 5-16.
	4. OPEN MAIN RECTIFIER.	
B. High ripple.	1. Defective filter capacitor C1 or C2.	1. Replace.

5-9. EXCESSIVE RIPPLE.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. At full load.	1. Defective filter capacitors C1 or C2.	1. Replace.
	2. Defective main rectifier.	2. Replace
B. Any load with 60-cycle ripple at output.	1. Mag. Amp. rectifier diodes leaky, CR1 or CR2.	1. Replace.

5-10. INSTABILITY.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Random large excursions.	1. Unstable input line.	1. Check input line.

SYMPTOM	POSSIBLE CAUSE	REMEDY
	2. Check intermittent resistor failure in amplifier.	2. See paragraph 5-16.
B. Gradual drift in one direction.	1. Check reference diode CR109.	1. See paragraph 5-16b.
	2. Check voltage divider resistors.	2. Replace.
	3. Check 1st stage of amplifier.	3. See paragraph 5-16b.
C. Excessive drift under heavy load only.	1. Excessive heat in cabinet.	1. Check air flow.

5-11. OSCILLATION.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Low frequency (motorboating).	1. Check setting of R101 or R104.	1. Reset.
	2. Check capacitors C101, C102 in amplifier.	2. Replace.
	3. Check capacitors C3 and C4 shunting the voltage sensing resistor divider network.	3. Replace.

5-12. REGULATION CHECK. Because of the inherently slight regulation exhibited by this power supply, it is impracticable to make a regulation check by observing a voltage measurement across the output terminals of the supply as the line or load is varied.

5-13. To accurately check the regulation, it is necessary to use an external source of DC voltage of approximately the same value as the power supply output, connected as shown in Figure 6 below. This DC bucking voltage can be either an electronic unit, or a group of batteries connected in series, furnishing a DC potential larger than the output voltage of the power supply under test. The voltmeter should have full-scale range of 0 to 5 or 10 volts (5-0-5 with center zero, if available), since it will be used to measure only the difference between two almost

equal voltages. The balance adjustment is used to bring the meter needle to approximately midscale before testing, so that the deviation above or below the normal output of the supply under test can be observed.

5-14. The dummy load is selected to draw full load current at the nominal output voltage of the supply. The difference between the voltmeter readings with the switch open and closed (allowing the needle to come to rest before reading), gives the static regulation in volts.

5-15. Dynamic regulation is measured by substituting a calibrated oscilloscope for the voltmeter, and measuring the maximum deflection as a dummy load of appropriate value is switched in and out of the circuit.

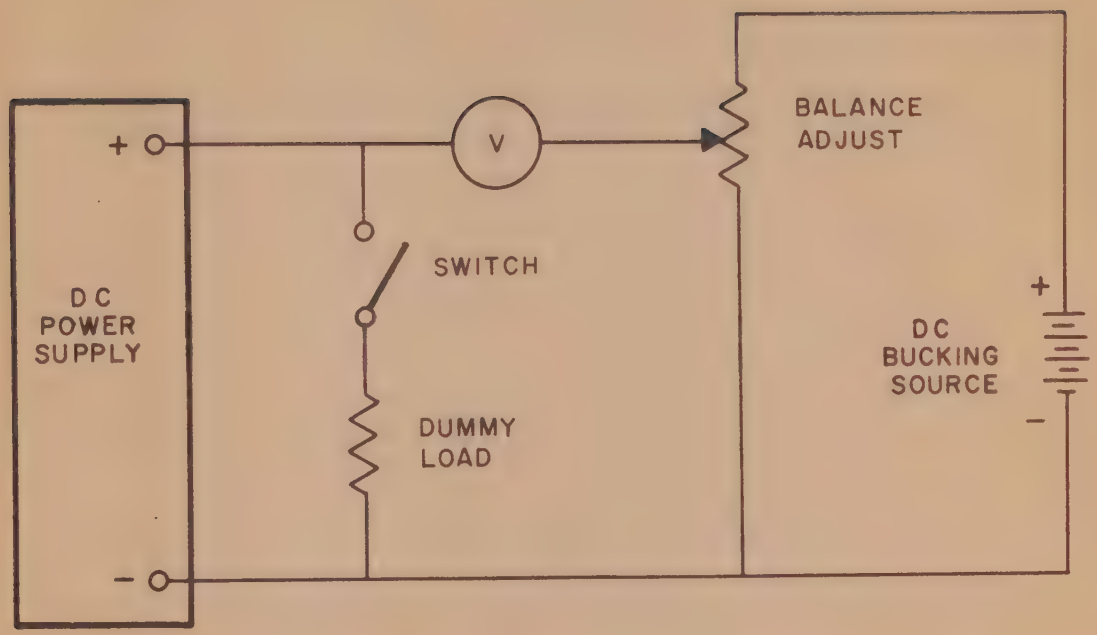
5-16. FEEDBACK AMPLIFIER CHECK. There are several methods which can be used in checking the performance and condition of the feedback amplifier.

Except for individually removing the transistors for a check by means of a transistor test set, and making continuity and resistance tests on the circuit and components, all methods require the amplifier to be energized with the proper potentials under the conditions found in the power supply for normal operation. For this reason, it is simplest to test the amplifier in position in the supply, first making certain that its DC power supply (transformer, rectifiers (diodes CR101-104), capacitor C201, diodes CR107, 108, 109, and resistors R119 and R202) is functioning properly. This can be quickly ascertained by checking the circuit voltages as indicated on the schematic diagram. Once this is done, the procedures given below can be used to check out the amplifier itself.

a. Voltage Check. The simplest and most rapid direct check of the amplifier is made by connecting a temporary jumper from the base of transistor Q104 to the base of transistor Q105, thereby balancing the amplifier input stage, and checking for balanced voltages on amplifier stages. Any obvious discrepancy will indicate a defective stage, and simple analysis will pinpoint the defective connection or component. Verification is then made by testing the component itself or repairing the connection.

b. Stability Check. A detailed check for improper drift and intermittent failure can be made by utilizing a test rig similar to that shown for precise regulation check in Figure 6 below. The voltage across the zener diode reference source CR109 is "bucked out", and monitoried by a 0 to 1-volt (or smaller scale, if available) high impedance DC voltmeter. Drift or random instability will be readily visible in this test. Output voltages of the successive amplifier stages and regulating diodes CR107 and CR108 can then be monitored in the same manner. When checking a given amplifier stage by this method, the output of the previous stage should be shorted, to prevent external

voltage variations from reaching the stage under test. When installing a new transistor in place of one shown to be defective, the stability check should be repeated, to make certain that the trouble has been eliminated.

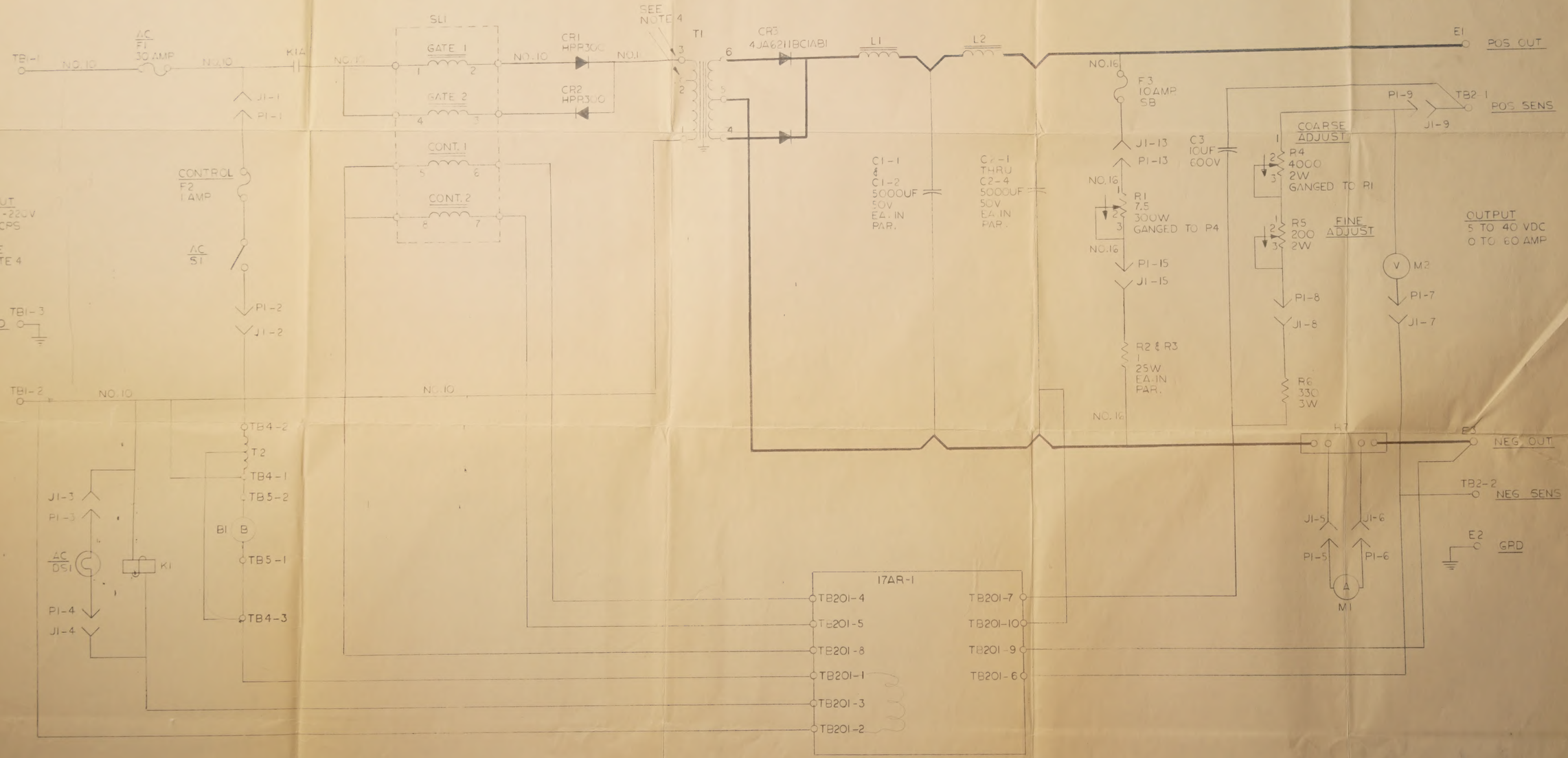

+
V
BALANCE
ADJUST
SWITCH
DC
POWER
SUPPLY
DUMMY
LOAD
+
DC
BUCKING
SOURCE
−
−

SECTION VI

APPLICATION NOTES

1-1. When TRM supply is used to feed equipment which requires high peak currents, an RC network, consisting of a 47-ohm resistor and a 200 to 500 mfd capacitor should be connected in the sensing line between the sensing terminals and the load. The resistor is the series element and the capacitor is the shunt element. This network prevents the peaks from blocking the amplifier thereby causing the supply to go out of regulation.

THESE DRAWINGS AND SPECIFICATIONS ARE THE PROPERTY OF NJE CORPORATION AND SHALL NOT BE REPRODUCED OR COPIED OR USED AS THE BASIS FOR MANUFACTURE OR SALE OF APPARATUS WITHOUT PERMISSION.



NOTES:
1. —— INDICATES NO.4 AWG. WIRE OR 1/16 X 1/2 BUSS BAR.
2. —— INDICATES NO.18 AWG. WIRE UNLESS OTHERWISE SPECIFIED.
3. FOR ADDITIONAL DWG. SEE : 17AR-1
4. USE TERMINAL 3 OF T1 FOR 220VRMS±10%, USE TERMINAL 2 OF T1 FOR 208VRMS±10%.

REVISIONS				
SYM	DESCRIPTION	DRAFTSMAN	DATE	APPROVAL
A	ECO. 000582	RC	2-20-60	

MICROFILM

NJE CORPORATION		KENILWORTH, N. J.
DRAFTSMAN	DATE	TITLE
DESIGNER		MODEL TRM-40-60A SCHEMATIC DIAGRAM
CHECKER		
ENGINEER		DWG NO. 401658 REV
APPROVED		SHEET OF

DIGITYPE PRESS, INC., BROOKLYN 17, N. Y. NJE FORM 104